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Fluoride removal by a continuous flow electrocoagulation reactor

Mohammad M. Emamjomeh [a,*], Muttucumaru Sivakumar [b]

[a] Environmental Health Engineering Group, Faculty of Health, Qazvin University of Medical Sciences, Bahonar Street, Qazvin, Iran
[b] Sustainable Water and Energy Research Group, School of Civil, Mining and Environmental Engineering, Faculty of Engineering, University of Wollongong, Wollongong, NSW 2522, Australia

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ABSTRACT

Long-term consumption of water containing excessive fluoride can lead to fluorosis of the teeth and bones. Electrocoagulation (EC) is an electrochemical technique, in which a variety of unwanted dissolved particles and suspended matter can be effectively removed from an aqueous solution by electrolysis. Continuous flow experiments with monopolar aluminium electrodes for fluoride removal were undertaken to investigate the effects of the different parameters such as: current density (12.5–50 A/m^2), flow rate (150–400 mL/min), initial pH (4–8), and initial fluoride concentration (5–25 mg/L). The highest treatment efficiency was obtained for the largest current and the removal efficiency was found to be dependent on the current density, the flow rate and the initial fluoride concentration when the final pH ranged between 6 and 8. The composition of the sludge produced was analysed using the X-ray diffraction (XRD) spectrum. The strong presence of the aluminium hydroxide [$Al(OH)_3$] in the above pH range, which maximizes the formation of aluminium fluoride hydroxide complex [$Al_nF_m(OH)_{3n-m}$], is the main reason for defluoridation by electrocoagulation. The results obtained showed that the continuous flow electrocoagulation technology is an effective process for defluoridation of potable water supplies and could also be utilized for the defluoridation of industrial wastewater.

1. Introduction

Fluoride ion in water has been found to have a significant effect against dental caries (WHO, 2004). Fluoride ion in water has both beneficial and harmful effects on the environment and the human. When an optimum amount of 1 mg/L is present in the drinking water fluoride helps prevent teeth decay but long-term consumption of water containing excess fluoride can lead to fluorosis of the teeth and bones (WHO, 2002). Waters with high fluoride content are usually found at the foot of high mountains and in areas with geological deposits of marine origin. Areas with these characteristics are found in the geographical belt from Syria through Jordan, Egypt, the Libyan Arab Jamahiriya, and Algeria to Morocco, and the Rift Valley through Sudan and Kenya. Another belt is the one stretching from Turkey through Iraq, the Islamic Republic of Iran, and Afghanistan to India, north Thailand, and China. Similar areas can be found in the Americas and in Japan and China (WHO, 2005). In Australia, the highest fluoride concentration was recorded as 13 mg/L in a water bore sample from Central Australia, however, it is not used for human consumption (Fitzgerald et al., 1999). The fluorosis problem is most severe in the two most populated countries of the world, China and India. WHO has recently estimated that 2.7 million people in China have the crippling form of skeletal fluorosis (WHO, 2002). An estimated 62 million people in India in 17 out of the 32 states are affected with dental, skeletal and/or non-skeletal fluorosis. The extent of fluoride contamination of water varies from 1.0 to 48.0 mg/L (Qian et al., 1999). The maximum acceptable concentration of fluorides in water is 1.5 mg/L (NHMRC and ARMCANZ, 2004). Fluoride also can be found in industrial wastewaters, such as in glass manufacturing industries (Sujana et al., 1998) and in high concentrations in semiconductor industries (Toyoda and Taira, 2000). The discharge of these wastewaters without treatment into the natural environment would contaminate surface and groundwater.

There are several defluoridation processes that have been tested globally, such as adsorption (Lounici et al., 1997), chemical precipitation (Parthasarathy et al., 1986; Sujana et al., 1998; Toyoda and Taira, 2000), electrodialysis (Amor et al., 2001), and electrochemical method (Ming et al., 1983; Cheng, 1985; Mameri et al., 1998). Lime addition is the most common method of the chemical precipitation technology and is used when high fluoride concentration is present. Lime and calcium salt precipitation of fluoride can reduce the residual fluoride concentration to 10–15 mg/L or even lower (Parthasarathy et al., 1986; Saha, 1993). Huang and Liu (1999) demonstrated that fluoride-containing wastewater from a semiconductor manufacturer can be effectively treated by

* Corresponding author. Tel.: +98 (281) 3344504; fax: +98 (281) 3368778.
E-mail address: m_emamjomeh@yahoo.com (M.M. Emamjomeh).

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